Threats Facing Lagoons along the North Coast of the Nile Delta, Egypt

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Abstract- **The primary objective of the present study was to highlight the major environmental hazards facing the coastal wetlands (Manzala and Burullus) of the Nile Delta using remote sensing. Natural and human-induced changes have been recorded in coincidence with global climate change and increased population stresses. Wetland areas and shoreline position have experienced drastic changes. Coastal zone management of this region requires public awareness of these concerns.**

Keywords- Threats; Burullus; Manzala; Lagoons; North; coast; Nile Delta; Egypt

I. INTRODUCTION

The Nile Delta is an "arcuate" delta (i.e arc-shaped), as it resembles a triangle or lotus flower when seen from space. It was formed in Northern Egypt due to the spread of the Nile River sediments north of Cairo for 160km. It is one of the world's largest river deltas extending from Alexandria in the west of Port Said in the east with a coastal exposure of about 240km on the Mediterranean Sea. The Nile Delta is characterized by the presence of several lagoons occupying a significant percentage of the delta surface area. The most important lagoons are the Manzala to the east and the Burullus at the central Nile Delta coast (Fig. 1). Historical accounts from the first Century A.D. reported that seven branches of the Nile once ran through the delta. Another later accounts reported that the Nile had only six branches by around the 12th Century. Since then silting and changing relief had closed all but two main outlets: the present day Damietta at the east and Rosetta at the west. Such defunct branches were, from the east: the Pelusiac, the Tanitic, the Mendesian, the Phatnitic (the present Damietta), the Sebennytic, the Bolbitic, and the Canopic (the present Rosetta) (Montasir, 1937). The Tanitic and Mendesian is now the outlet of the Manzala lagoon at El-Gamiel and El-Deiba villages along the Mediterranean Sea, respectively. On the other hand, the Sebennytic is the outlet at the Burullus lagoon. Since the delta no longer receives an annual supply of nutrients and sediments from upstream due to the construction of the Aswan High Dam in 1964, the reduction in annual silt deposits has contributed to erosion of the delta coastal edges, the coastal lagoons have been deteriorated due to disposal of wastewater, and the soils of the floodplains have become poorer leading to the addition of large amounts of fertilizers. The main objective of this study is to highlight the constraints facing the coastal zone management of the Nile Delta, focusing on its coastal lagoons. We will utilize satellite images to monitor surface area change of the coastal lagoons, to highlight vulnerable locations to coastal erosion, and to map locations prone to inundation by sea level rise. The results of this investigation should throw light to decision makers to be aware of the integrated coastal zone management.

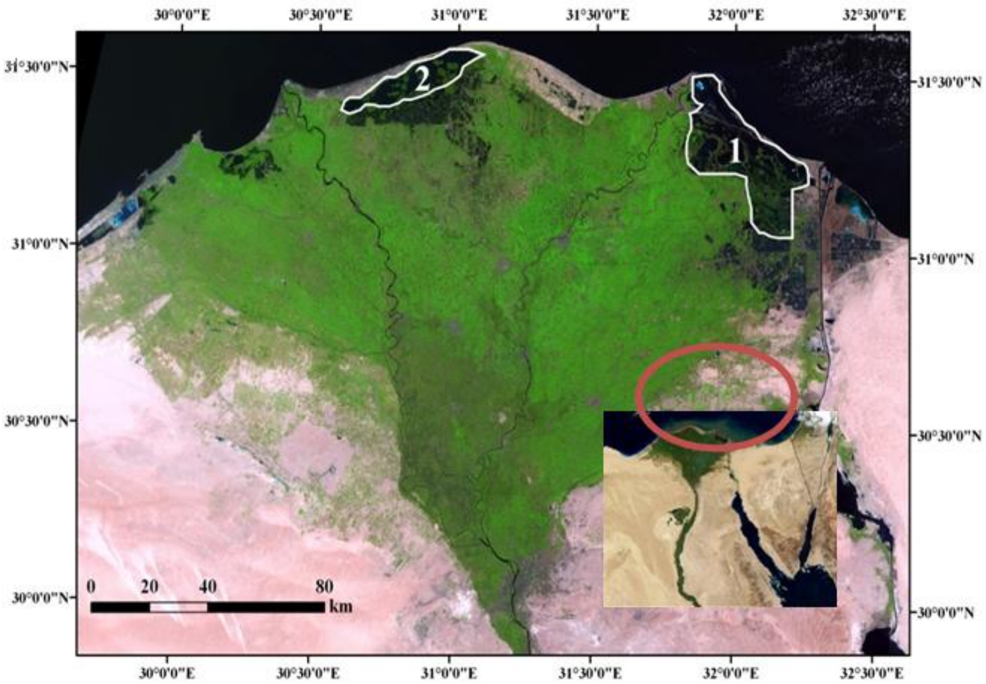

Fig. 1 False color composite satellite image of the Nile Delta showing the locations of the Manzala (1) and Burullus (2) lagoons

II. MATERIALS AND METHODS

Two types of data sets were utilized to achieve the objectives of the present study (Table Ⅰ). The first is a set of Landsat satellite images acquired from the (MSS and TM sensors). The MSS images were acquired in 1973 and the TM images were acquired in 2003. The second source of data is a set of two seamless digital elevation models (DEM) acquired from the Shuttle Radar Topography Mission (SRTM) in 2000.

TABLE Ⅰ SATELLITE DATA UTILIZED IN THE PRESENT STUDY

Sensor	Acquisition Date	Path	Row	Spatial Resolution
MSS	January 1973	190	38	60
MSS	May 1973	191	38	60
TM	August 2003	176	38	30
TM	September 2003	177	38	30
SRTM	February 2000	176	38	90
SRTM	February 2000	177	38	90

Atmospheric correction was the first process to be applied to the landsat satellite images. Atmospheric correction was carried out using the dark object subtraction method of Chavez (1996). Then, geometric correction was performed through image-to-image registration to the Universal Transverse Mercator Projection (UTM / zone 36 WGS 84) using a first-order polynomial transform. At least 20 prominent well-distributed ground control points (GCP) were carefully chosen in the master TM image and matched on the other images, and then the nearest neighbor resembling method was applied. The root mean square error (RMSE) was less than 0.5-pixel for the registered TM image and less than 1.0 pixel for other two MSS images revealing an accurate rectification. ERDAS Imagine software was used to perform image processing of the satellite images. Two subset images were created in each of the MSS and TM images to show the boundaries of the two lagoons: Manzala and Burullus during 1973 and 2003 (Fig. 2). We applied the approach of water index to highlight the water body of each lagoon in each date. The water index, which is termed the normalized difference water index (NDWI) (McFeeters, 1996) was calculated in the MSS images using the following equation: (Green - NIR) / (Green + NIR), where the Green and NIR bands are the digital numbers (DN) in the green and near infrared bands in the two MSS images of 1973. On the other hand, the other water index which is termed the modified normalized difference water index (MNDWI) (Xu, 2006), was calculated in the two TM images using the equation: (Green - MIR)/(Green + MIR), where the Green and MIR are the reflection in the green and middle infrared bands of the TM images. After assigning the threshold value of water in the two indices, two thematic maps were generated showing the spatial extent of the water body of the two lagoons in 1973 and 2003. The surface area was then estimated and compared. The dynamic movement of the coastline along the two lagoons in terms of advancing by accretion or retreating by erosion was highlighted and measured using ArcMap software by digitizing the shoreline position in the MSS images of 1973 and overlying this position above the satellite image (TM) of the 2003. Two thematic maps showing the relative coastline position in each date were prepared to present the regions, which experienced erosion and those exposed to accretion. The topography of the coastal zone of the Nile Delta is analyzed using the digital elevation models acquired for the region. These two seamless, finished and 90-m spatial resolution images were processed separately. In ArcMap software, the two digital elevation models were displayed and each image was classified into two elevation levels: below 1-m and above 1-m elevation level. This classification was intended to highlight areas of the two lagoons and their surroundings which are prone to sea level by 1-m above its current zero level due to the eustatic global sea level rise. The boundaries of the two lagoons were digitized and superimposed the two classified digital elevation model.

III. RESULTS AND DISCUSSION

The Nile Delta in general and its coastal lagoons in particular witness three major natural and human-induced threats: 1- shrinking of the water body due to drying and siltation; 2- erosion of the coastal strip; and 3- accelerated subsidence. The controlling factors for these threats are mainly attributed to the increased human pressure upon these ecosystems due to population growth, the interference with the hydrology of the Nile River by damming and flow control, and the land subsidence of the sediment column beneath these lagoons. Remote sensing technology has provided an indispensable tool for mapping and monitoring coastal changes at the Nile Delta coastal lagoons. The premise in using satellite data is based on the fact that there is a good record of satellite images archived since early 1970’s. In addition, satellite data supplies information in the near infrared spectrum which affords information beyond surveying by human eyes. Moreover, the temporal and spatial as well as swath covering of wide geographic regions are positive facets over the traditional methods of surveying.

The environment of many worlds’ wetlands, including the Nile Delta wetlands, has been changed to other land use, such as agricultural and urban purposes, which has imposed a global concern (Haack, 1996). The coastal wetlands at the Nile Delta of Egypt are under the threat of human impact, due to the potential human stresses caused by the accelerated population growth. Recent assessment of the change of the surface area of the Manzala lagoon using water indices reveals a drastic shrinking of its area from 1100km^2 in 1973 to 720km^2 in 2003 (El-Asmar and Hereher, 2011). The Manzala lagoon, which was formed more than 3000 years ago (Benninger, 1998), is the largest coastal lagoon along the Nile Delta. This lagoon was considered the major source of fish production throughout the entire northern Egypt. Moreover, Manzala lagoon is one of the most important Egyptian wetlands for water birds and a migration route of birds from Europe to Africa across the Mediterranean Sea (Ayache et al., 2009). The occurrence of densely populated urban areas around the peripheries of the lagoon associated with dumping of untreated sewage and agricultural effluents have tremendously impacted the environment of the lagoon in terms of its area and the quality of the water body. The construction of the International Coastal Highway and El-Salam irrigation canal and the conversion of significant areas from the lagoon into agricultural land are the primary sources of the lagoon degradation. It is observed that there has still been population stresses upon the lagoon environment until present time.

Moving west toward the Burullus lagoon, it becomes obvious that there had been a significant decrease of the lagoon area between 1973 and 2003. The NDWI and MNDWI calculations of the water body reveals that the area of the

lagoon was about 425km^2 in 1973 and decreased to about 265km^2 in 2003 as appeared in the MSS and TM images. Much of the area loss was due to the conversion of the lagoon body into reclaimed agricultural land. The disposal of agricultural wastes from the farm lands south of the lagoon represents a significant threat to the water quality. This is manifested by the increased turbidity and nutrient concentrations (such as phosphorous and nitrogen) in the lagoon water (Hereher el al., 2011).

After the closure of the High Dam at Aswan during 1960's and the cut-off of sediments reaching the Mediterranean Sea, the entire coastal zone of the Nile Delta has witnessed severe erosion with rate changes from 113m\yr to 6.5m\yr. (Figs. 3, 4). Comparing the shoreline position using old and recent satellite images reveals maximum erosion rates at Rosetta, Baltim, and Damietta (Figs. 3-6). The coastal strip separating the Nile Delta lagoons from the Mediterranean Sea, which is mainly described as a sandy bar (El-Asmar, 2000 & 2002a) covered by coastal sand dunes, is under significant threat due to the leveling processes and removal of sand dunes (El-Banna, 2004). The combination of coastal erosion with leveling of the separating bar constitutes a direct concern particularly if the sea level rise issue is taken into consideration. Rates of erosion and shoreline retractions at the Manzala lagoon were detected ranging from 10m/yr to 41m/yr. (El-Asmar and Hereher, 2011), while rates of coastal erosion and shoreline retraction ranging from 1.3m/yr up to 5m/yr. were detected at the Burullus lagoon (Hereher and El-Asmar, under publication). Although the government armored long tracts of the Nile Delta beaches, there are still many other sectors without protection and should be highlighted for decision makers.

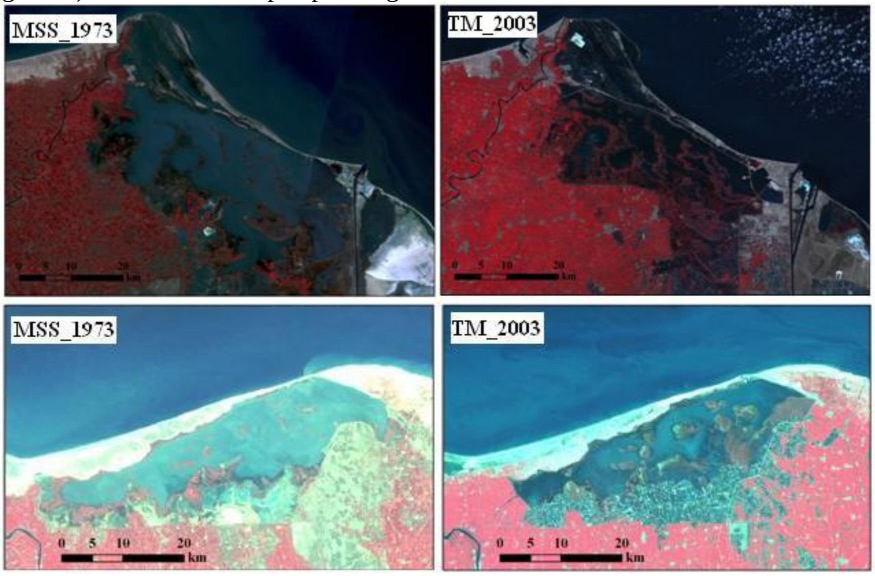

Fig. 2 False color composites of the Lake Manzala showing the water body in 1973 and 2003

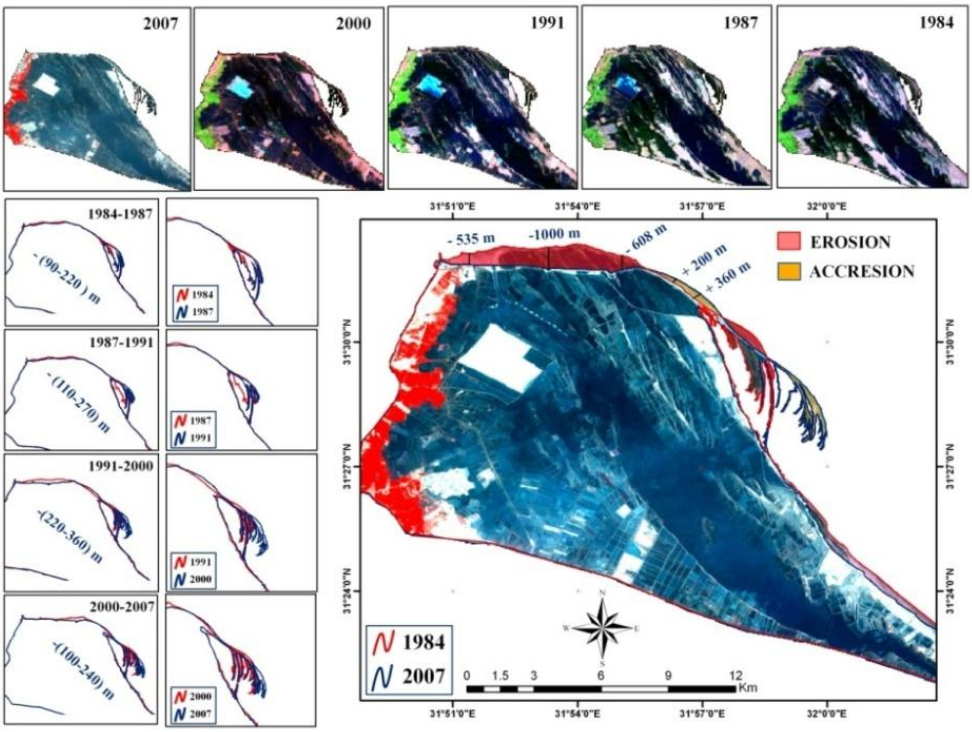

Fig. 3 Erosion pattern at the headland of Damietta Promontory and the shoreline of the Manzala lagoon as detected by satellite images (El-Asmar et al., under publication)

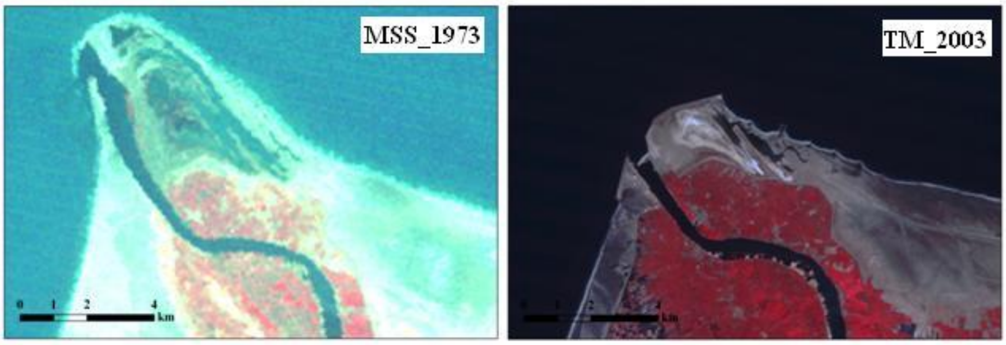

Fig. 4 Erosion pattern at the headland of the Rosetta promontory west of the Burullus lagoon

The configuration of the shoreline position along the coastal front of the two Nile Delta lagoons is shown in Figs. 5, 6. The shoreline has undergone noticeable episodes of accretion and erosion. The primary reason for the coastal erosion occurred along these shorelines is the change of the hydrorgraphy of the Nile River regime through damming and flow control. The severity of the coastal erosion is observed greater at the Manzala lagoon than at the Burullus lagoon coastal zone. This difference may be attributed to the closeness of the Manzala lagoon to the Damietta River Nile branch; the source of sediments before constructing the Aswan High Dam. Maximum coastal erosion was encountered at about 46 m/year near the mouth of the Nile River (El-Asmar and Hereher, 2011). However, some accretion beaches were observed near the Suez Canal. The significant concern regarding erosion of the narrow coastal strip separating the Manzala lagoon from the Mediterranean Sea arises not only from the inundation of the lagoon body by the seawater but also from the potential damages that could occur to the infrastructural facilities established near Port-Said City where the gas liquefaction companies are settled (El-Asmar, 2002a).

The situation has less a degree of concern along the Burullus lagoon. Although the beach along the coastal strip separating the Burullus lagoon from the Mediterranean Sea has witnessed alternation of erosion and accretion pockets, the existence of coastal sand dunes at this coastal bar is considered a natural barrier protecting the lagoon from flooding by the sea (Hereher, 2009). However, the removal of these coastal sand dunes could be of a great concern threatening the entire coastal zone of the Nile Delta.

The most recent environmental issue regarding the entire coastal plain of the Nile Delta is the growing concern about the global sea level rise and the drowning of substantial areas of the Nile Delta. Hereher (2010) reported that there already exists about 18% of the Nile Delta surface area below the mean sea level and if there is a rise of the sea level by 100cm, a total of about 31% of the delta should be theoretically under the seawater. Sea level rise was studied by Frihy (1992) at the northern boundaries of the Nile Delta at Alexandria and Port-Said to be 2mm/year and 2.4mm/year, respectively. The toll of the anticipated sea level rise includes: loss of productive agricultural lands, accelerated coastal erosion, contamination and loss of coastal lagoons, threat to recreational beach communities and migration of millions of people southward with consequent serious socio-economic impacts (El-Raey et al., 1999, 2000; Hereher, 2010). The last but not least include the expected damage in gas, oil and petrochemical industries concentrated along this coastal strip of sand bar separating the Mediterranean sea from Manzala lagoon (El-Asmar, 2002a).

Analysis of the digital elevation models of the study area indicates a horrible situation in case of the rise 1-m of the sea above its current level. In this situation, both of the two lagoons will be inundated and their boundaries will be eradicated, leaving just remnants of isolated islands in the Manzala lagoon and completely disappearance of the boundaries and islands of the Burullus lagoon (Figs. 7, 8).

Fig. 5 The position of the shoreline along the coast of the Manzala lagoon in 1973 (white line) compared with the recent position as appeared in the TM image of 2003

Fig. 6 The position of the shoreline along the coast of the Burullus lagoon in 1973 (white line) compared with the recent position as appeared in the TM image of 2003

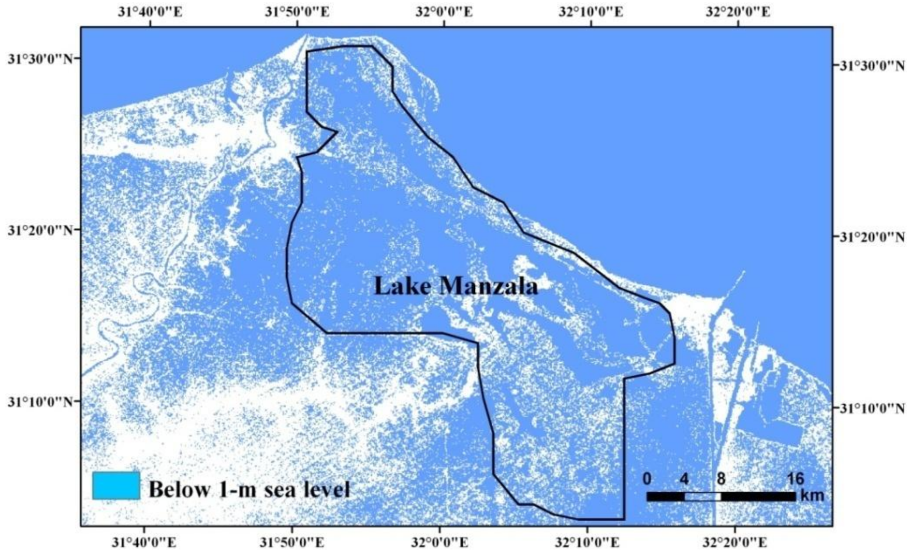

Fig. 7 The DEM of the Manzala lagoon showing the location of the sea if it rises 1-m above its level

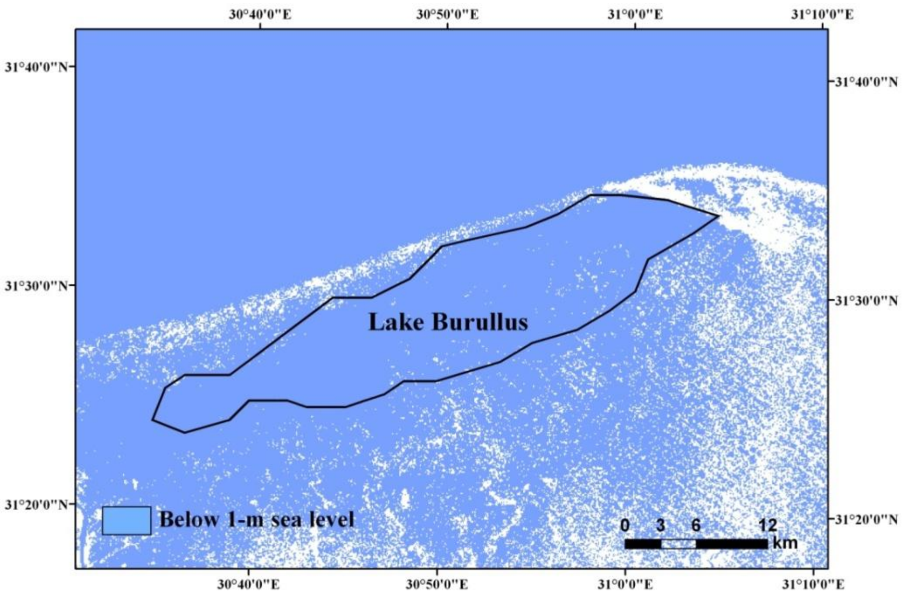

Fig. 8 The DEM of the Burullus lagoon showing the location of the sea if it rises 1-m above its level

The concern of the drowning by the seawater could be triggered if we take into account the fact that the sediment column of the Nile Delta is subsiding due to a tectonic induced movement (Stanley, 1988) and may be due to the compaction of the sediments under its own weight. Recent subsidence rates are estimated to between 3.55mm/year (Stanley, 1990; El-Asmar, 2002b). The combination of these concerns constitutes the significant challenge facing any coastal zone management of the Nile Delta region. Although the government has constructed ambitious plans for development of the coastal zone of the Nile Delta, public awareness of these challenges and constraints is limited. For example, people excavate and remove huge quantities of coastal sand dunes which protect the coast from seawater intrusion. In addition, the waste disposal into the main wetlands of the Nile Delta continues without any primary treatment before discharge into the water body.

IV. CONCLUSIONS

The northern lagoons of the Nile Delta of Egypt are exposed to two types of environmental alarms: 1- actual threats, such as drying of substantial areas of the lagoons, significant shoreline erosion and disposal of untreated wastes; and 2- potential threats, such as drowning by the seawater due to the eustatic sea level rise; tectonic lowering and removal of coastal sand dunes. Most of these hazards are human-induced; however, delta subsidence and sea level rise belong to the natural hazards. These concerns constitute the major challenge facing any coastal zone management of the Nile Delta.

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